Farmerbots: a new industrial revolution

by James Mitchell Crow

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Can robots do better than farmers by feeding the planet's rising population while helping to protect the environment?

NEXT time you stand at the supermarket checkout, spare a thought for the farmers who helped fill your shopping basket. They are finding life hard right now, and you can be sure this will mean higher food prices for you, and tougher times for the millions in the world for whom food shortages are a matter of life and death. Worse, studies suggest that the world will need twice as much food by 2050. Yet while farmers must squeeze more out of the land, they must also reduce their impact on the environment. All this means rethinking how agriculture is practised, and taking automation to a whole new level.

On the new model farms, precision will be key. Why dose a whole field with chemicals if you can spray only where they are needed? Each plant could get exactly the right amount of everything, no more or less, an approach that could slash chemical use and improve yields in one move. But this is easier said than done; the largest farms in Europe and the US can cover thousands of hectares. And that is why automation is key to precision farming. Specifically, say agricultural engineers, precision farming needs robot farmers.

Soon, we might see fields with agribots that can identify individual seedlings and coax them along with tailored drops of fertiliser and measured sips of water. Other machines would distinguish weeds and dispatch them with a microdot of pesticide, a burst from a flame gun or a shot from a high-power laser. These machines will also be able to identify and harvest all kinds of ripe vegetables.

Robots could bring major changes, too, in jobs and how we work, in the soil and its quality, and in how much energy, and thus carbon, goes into farming. They could reduce pollution and water use. The most visible change, though, for ordinary people, could be in how farmland looks. Crops could be planted in small, geometrically arranged fields, while fruit farms are filled with arrays of two-dimensional trees. Robofarmers might even influence the type of fruit and vegetables that reach our shelves.

More than a century of mechanisation has already turned farming into an industrial-scale activity in much of the world, with farms that grow cereals being among the most heavily automated. But a variety of other crops, including oranges and tomatoes that are destined for processed foods, are picked mechanically. On thousands of dairy farms cows are now milked by robots. These and other products arrive at your local store untouched by human hands.

Yet the next wave of autonomous farm machinery is already hard at work. You have probably seen it and not even noticed, for these robots are disguised as tractors. Many of today's tractors are self-steering, use GPS to cross a field, and can even "talk" to their implements - a plough or sprayer, for example. And the implements can talk back. "A mechanical weeding tool will tell the tractor 'you are going too fast', or 'move to the left'," says Simon Blackmore, who researches agricultural technology at Harper Adams University College in Shropshire, UK. Such systems are becoming the norm, he says.

Farm vehicles are also beginning to talk to each other. A John Deere system on sale this year allows a combine harvester, say, to call over a tractor-trailer so the driver can unload the grain. German firm Fendt has created paired tractors, one driven manually with the second self-steering and mimicking the first tractor's movements in an adjacent row. The system can effectively halve the time a farmer spends in the field – and this is just the start.

However, when fully autonomous systems take to the field, they will look nothing like tractors. With their enormous size and weight, today's farm machines have significant downsides: they compact the soil, reducing porosity and killing beneficial life, meaning crops don't grow so well. Compaction also increases erosion by rainwater run-off. "Why do we plough? Mainly to repair the damage that we have caused with big tractors," says Blackmore. "Up to 80 per cent of the energy going into cultivation is there to repair this damage. Surely there is an opportunity to do things in different ways."

Fleets of lightweight autonomous robots have the potential to solve this problem, Blackmore believes. Replacing brute force with precision is key, he says. "A seed only needs one cubic centimetre of soil to grow – if we cultivate just that we only put tiny amounts of energy in and the plants still grow nicely."

These lightweight robots could remove the need for ploughing altogether, significantly reducing the amount of energy, and thus carbon dioxide emissions, coming from farming. And with less compaction, the soil keeps its structure and beneficial organisms, and is able to absorb more water and stay fertile for longer.

Autonomous robots with these kinds of abilities are already showing their mettle in field trials. These agribots need to have three key abilities: to navigate, to interpret the scene in front of them, and to be able to help the farmer, by blasting a weed, applying a chemical or harvesting the crop.

Navigation systems are the simplest part of the equation, particularly with the emergence of a high-precision satnav technique called RTK-GPS, which enables machines to locate themselves to within 2 centimetres. Arno Ruckelshausen from the University of Applied Sciences in Osnabrück, Germany, is developing this for a modular robot farmer called BoniRob. This four-wheeled field rover uses spectral imaging cameras to pick out green plants against brown soil. It then records the location of individual plants and repeatedly returns to each one during the season to monitor its growth (Landtechnik, vol 67, p 37).

Laser weed gun

Eliminating weeds is a particularly desirable aim, since they reduce yields in some crops by more than 50 per cent. So next, Ruckelshausen intends to fit this robot with a precision spraying system – based on an ink-jet printer – that can apply microdots of herbicide to the leaves of weeds. He calculates this could cut chemical use by up to 80 per cent. Even taking into account the initial investment in the robot, this would end up being cheaper than conventional weeding, Blackmore calculates. There are obvious benefits for biodiversity, too, by minimising the number of plants that are killed by herbicides. What's more, applying herbicide isn't the only way robots could kill weeds: prototypes have wielded flame guns and lasers to burn weeds, something that would be very useful for organic farming.

Similar savings are possible with fertiliser: field trials have shown that by using sensors to assess an individual wheat plant's nitrogen levels, a robot can tailor the amount of fertiliser it gives and reduce the overall amount used by more than 80 per cent, with no loss in yield (Soil Science Society of America Journal, vol 73, p 1566). The decrease in fertiliser use, combined with reduced water run-off from less compacted soil could mean healthier rivers and waterways. Not to mention the fact that industrial production of fertiliser is a huge contributor to carbon emissions.

The next challenge is how to distinguish weed from crop. Researchers are developing machine vision systems that use the shape of the leaves to distinguish between, say, weeds and sugar cane. Progress is slow, though, says Salah Sukkarieh, a robotics researcher at the Australian Centre for Field Robotics in Sydney, because of a lack of funding. "If I had the money for agricultural robots that I have from mining and defence projects, I'd solve it. But there's just not enough money in farming. We have to learn from other industries, it's a trickle-down effect," he says. Still, machine vision should be ready in around three years, he predicts.

Blackmore, too, sees no technological reason why agricultural robots can't go commercial. Tests of robots with machine vision such as the Danish HortiBot have shown they can identify weeds in a field and spray them with precise amounts of pesticide. Other tests have shown that robotic irrigation systems can cut water use by up to half. "It's just a question of finding the investment. The technologies have all been developed," he says.

In Japan, the government has taken the matter into its own hands. The country currently grows 40 per cent of its own food, making it more reliant on imports than any other nation, but the government aims to increase this to 50 per cent within the next decade. And with an ageing population shrinking the pool of potential farm workers, the country is turning to robots.

Noboru Noguchi at Hokkaido University is leading a five-year, $8 million project funded by Japan's Ministry of Agriculture, Forestry and Fisheries to bring agribots to market. The project aims to automate everything from planting through to harvest, and will focus on Japan's three staple crops: rice, wheat and soya beans. By 2014, the team plans to be pilot testing its agribots on farms. "Five years from now, we want to be selling them," Noguchi says.

One big concern for Noguchi is the risk that a robot might hit hikers or stray cattle. So he is working with German engineering company Bosch to develop robots equipped with lasers and ultrasonic sensors that monitor their surroundings and jam on the brakes if a collision is imminent. As a back-up, touch-sensitive bumpers stop the robot should it strike anything.

After Japan, the next places to feel the pinch of farm labour shortage – and where robot farmers are likely to appear the soonest – are North America and western Europe. And it is a similar story in rapidly developing nations such as China. "Work in agriculture is not interesting, prestigious or usually very well paid. It is physically demanding and dirty – people prefer to go to the cities and work in factories or in office jobs," says Eldert van Henten, a robotics researcher at Wageningen University in the Netherlands. "While the population is growing and needs to be fed, a rapidly shrinking number of people are willing to work in agriculture."

Linda Calvin, an economist at the US Department of Agriculture, and Philip Martin at the University of California, Davis, have studied trends in mechanisation to predict how US farms might fare as the labour force shrinks. So far, migrant workers mainly from Mexico have kept the numbers high, but the flow of immigrants is slowing and many in the US are returning home. The US Department of Labor's National Agricultural Workers Survey has interviewed more than 50,000 farm workers during the past 25 years. More than half of respondents to recent surveys were illegal immigrants, yet even amongst this group, where legal status, education and language act as barriers to other employment, most give up farm work after less than a decade for less physically demanding jobs.

Rising employment costs have driven the adoption of labour-saving farm technology in the past, Calvin and Martin say, citing the raisin industry as an example. In 2000, a bumper harvest crashed prices and, with profits squeezed, farmers looked for savings. With labour one of their biggest costs – 42 per cent of production expenses on US farms, on average – they started using a mechanical harvester adapted from a machine used by wine makers. By 2007, almost half of California's raisins were mechanically harvested and a labour force once numbering 50,000 had shrunk to 30,000.

Agribots may not be good news for labourers who depend on the land for their living, but what about farmers themselves? While studies suggest that robotic milking makes little impact on overall profits, the machines save dairy farmers the chore of daily milking. But calculations by Blackmore suggest that agribots could bring significant financial benefit, reducing weeding costs by about 20 per cent per hectare in cereal or sugar beet fields. Gains should be larger for organic farmers since labour makes up more than 50 per cent of their total costs. A study of organic farming in Denmark suggests agribots could halve the cost of weeding, once machinery and maintenance costs are taken into account.

Bot-friendly farms

Josh Stride from the UK's Soil Association – which backs organic farming – is excited by the prospect of technology that can reduce chemical use. But, he warns, we also need to appreciate the risks. "The introduction of any new technology should be contingent on its ability to provide demonstrable benefits."

Can agribots reduce the price of groceries, say? Perhaps, says Blackmore. So many forces control the price of food, from the weather to supermarket price wars, that it is hard to tell whether automation will make fruit and veg any cheaper in the long run, he says. Yet making farming less energy-intensive should give us a chance to keep prices down.

However, the widespread adoption of agribots might bring other changes at the supermarket. Lewis Holloway, who studies agriculture at the University of Hull, UK, says that robotic milking is likely to influence the genetics of dairy herds as farmers opt for "robot-friendly" cows, with udder shape, and even attitudes, suited to automated milking (Journal of Rural Studies, in press). Similarly, he says, it is conceivable that agribots could influence what fruit or veg varieties get to the shops, since farmers may prefer to grow those with, say, leaf shapes that are easier for their robots to discriminate from weeds.

Almost inevitably, these machines will eventually alter the landscape, too. The real tipping point for robot agriculture will come when farms are being designed with agribots in mind, says Sukkarieh. This could mean a return to smaller fields, with crops planted in grids rather than rows and fruit trees pruned into two-dimensional shapes to make harvesting easier. This alien, geometrical farmscape tended by robots is still a while away, says Sukkarieh, "but it will happen."

Van Henten agrees. "When we started on robotics in the mid-90s, growers were laughing and sceptical," he recalls. "But when we demonstrated a cucumber harvester, they asked if they could buy it tomorrow."

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